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Design of a
Swing Highway Bridge

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DESIGN OF A SWING HIGHWAY BRIDGE

BY

JOHN SCHUYLER BATES

THESIS FOR DEGREE OF BACHELOR OF SCIENCE
IN CIVIL ENGINEERING

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS

PRESENTED JUNE 1902

UNIVERSITY OF ILLINOIS

May 30 1902

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

John Schuyler Bates

ENTITLED Design of a Swing Highway Bridge

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering

Ira O. Baker

HEAD OF DEPARTMENT OF Civil Engineering

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PART II

Outline of Part II

1. Introduction

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3. The Scope of the Problem



The following design of a swing bridge is made to meet conditions of highway traffic such as exist at Round Hecolisin.

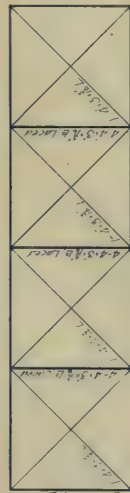
The diagram on the following page shows the location of the draw span in the bridge for the above location.



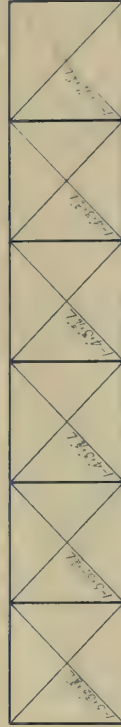
DESIGN FOR A DRAW-SPAN
FOR A
Highway Bridge over Chippewa River at Durand Wis.
SCALES-1 1/2"=10 ft. 1 1/4"=30 ft.
JUNE 1902
J. B. B. Co.

Highway Bridge over Chippewa River at Durand Wis.

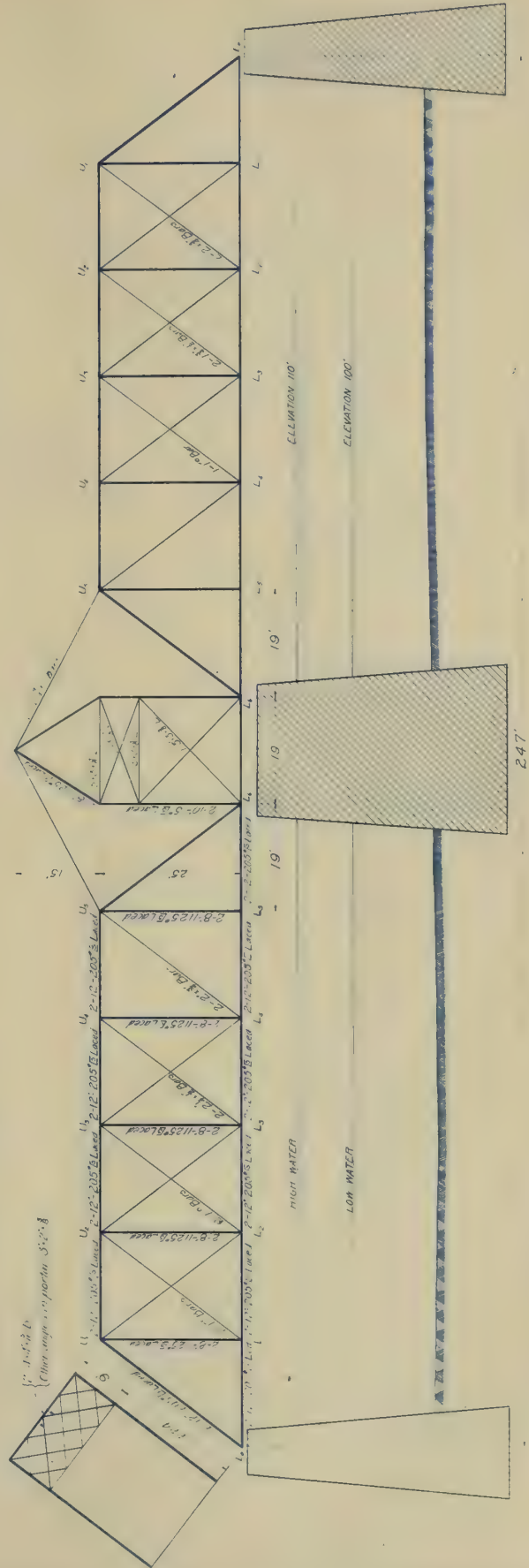
SCALE 3-1 IN = 10 ft 1 IN = 30 ft JUNE 1902.



Top Laterals



Bottom Laterals



HIGH WATER

LOW WATER

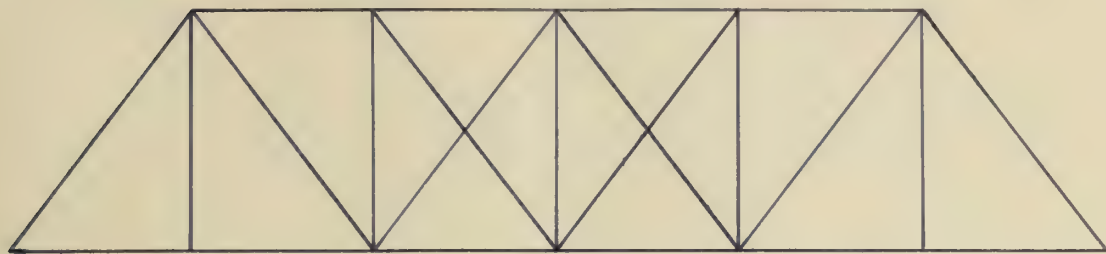
247.

PART 1

Design of Pratt Truss.

Act. I

Dimensions of Truss



Span 114 feet for each truss, or 247 ft. total length of draw. The truss is of the Pratt type. The height is 25 feet. This minus the floor system and portal will leave ample clearance, 15 feet being specified by Cooper. The panel length is 19 feet. This gives an inclination to the inclined members of $37^{\circ} 14'$ which is an economical inclination. There will be six panels in each truss. The required roadway is 18 feet. The truss will be about 12 inches wide, so the distance c. to c. of trusses will be about 19 feet.

The bridge will be designed according to Cooper's Specifications (1901), for Class D, using medium steel.

Art. II.

Design of Joist.

The roadway is to be 18 feet clear. With a spacing of 2 feet between joists, this will give nine spaces and ten joists. Eight I beams and two channels will be used.

With 80 lbs. per sq. ft. of floor surface for live load, the total uniform load on one stringer = 3200 lbs.

$$M = \frac{1}{8} W L = \frac{1}{8} \times 3200 \times 228 = 91200 \text{ inch-lbs}$$

The weight of the 3-inch pine floor at $3\frac{1}{2}$ lbs. per board foot = 400 lbs. per joist.

$$M = \frac{1}{8} \times 400 \times 228 = 11400 = M \text{ due to floor}$$

$$\begin{array}{r} 91200 = \text{live load} \\ \hline 102600 = \text{total } M. \end{array}$$

With live load of 6 tons on two axles 10 ft. centers, the load on one wheel = 1.5 tons. Max. moment in joist is when one wheel is at the center.

$$M = \frac{1}{4} T L = \frac{1}{4} (3000) \frac{2}{3} \times 228 = 114000 = M \text{ due to con. l.}$$

$$\begin{array}{r} 11400 = \text{floor} \\ \hline 125400 = \text{total } M. \end{array}$$

For a 7"-15" I beam, $I = 36.2$, $C = 3.5$

$$S = \frac{M C}{I} = \frac{125400 \times 3.5}{36.2} = 12120 \text{ lbs. exclusive of}$$

the weight of the joist. Including the weight of the joist the moment is $125400 + 1748 = 127148$ and $S = 127148$.
Let us allow 13000 lbs. so this will insure
7 inch channels must be used
on the inside.

Art. III.

Design of Floor Beam.

Three inch pine flooring at $3\frac{1}{2}$ lbs.
per board foot - $3 \times 3\frac{1}{2} = 10.5$ lbs. per sq. ft.
 $10.5 \times 342 = 3591$ lbs. = weight of flooring per
floor beam.

$15 \times 19 = 285$ lbs. wt. of one joist (I)

$9.75 \times 19 = 185$ " " " " (L)

$285 \times 8 = 2280$ lbs. wt. of I's in one panel.

$185 \times 2 = 370$ " " " [S " "

3591 " " " flooring.

6241 " dead load on one floor beam
exclusive of the weight of the beam.

$M = \frac{1}{8} \times 6241 \times 216 = 168507$ - dead load moment.

Live load - 80 lbs. per sq. ft.

$P = 80 \times 342 = 27360$ lbs.

$M = \frac{1}{8} \times 27360 \times 216 = 738720$.

$$\begin{array}{r} 168507 \\ 738720 \\ \hline \end{array}$$

907227. total M on floor beam.

Total weight of one 18"-55I beam - 990 lbs
M due to the weight of the floor beam -

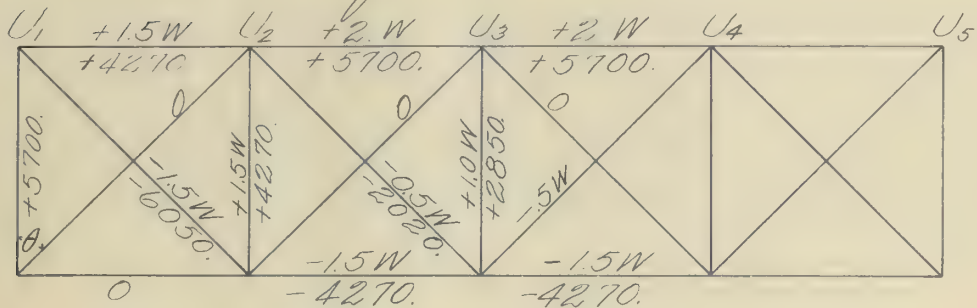
$$\frac{1}{8} \times 990 \times 216 = 26730$$

$$\begin{array}{r} \text{Total M in floor beam} = 907227 \\ 26730 \\ \hline 933957 \end{array}$$

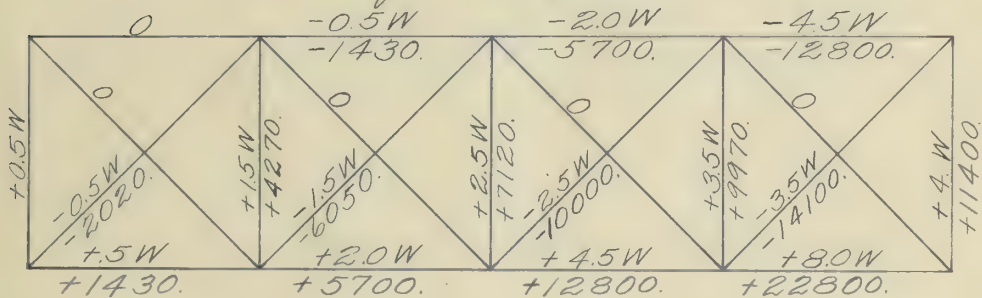
$$S = \frac{933957 \times 9}{7956} = 10560 \text{ lbs.}$$

Cooper allows 13000 lbs. therefore the 18" I beam will carry the load.

Art. IV.
 Determination of Stresses.
 A, Top Lateral System.
 Bridge Closed



Bridge Open.



$$W = 150 \times 19 = 2850 \text{ lbs.}$$

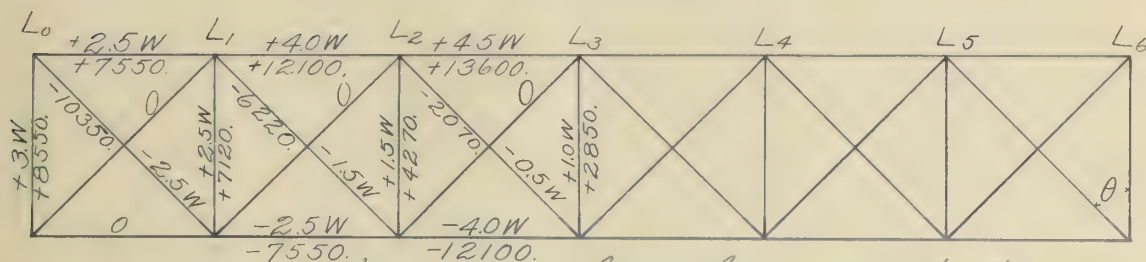
$$\tan \theta = 1.0, \sec \theta = 1.414$$

$$W \tan \theta = 2850$$

$$W \sec \theta = 4030$$

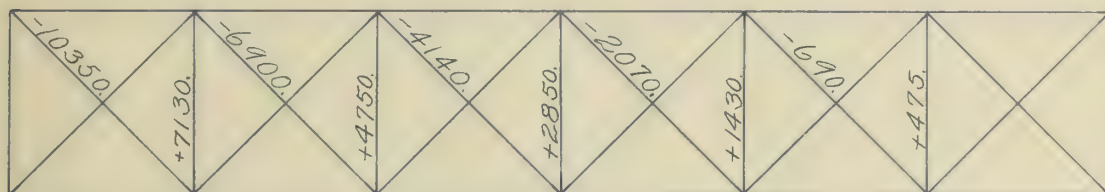
B

Bottom Lateral System.
 Bridge Closed.
 Dead Load.

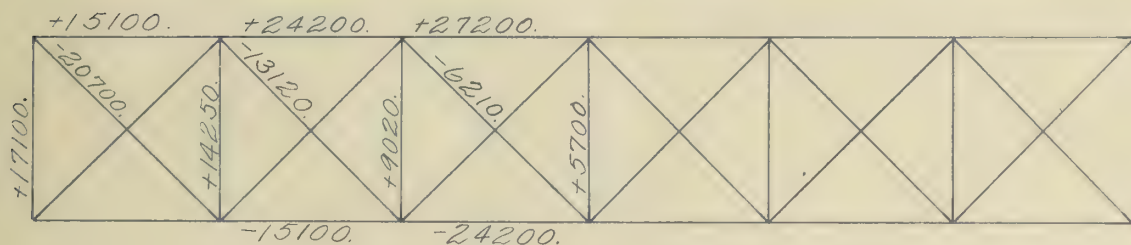


± 8550 in each panel of lower chord due to stress in end post.

Live Load.



Max. and Min. Stresses.



$$W = 150 \times 19 = 2850 \text{ lbs.} \quad W \tan \theta = 3020$$

$$\theta = 46^\circ - 33'$$

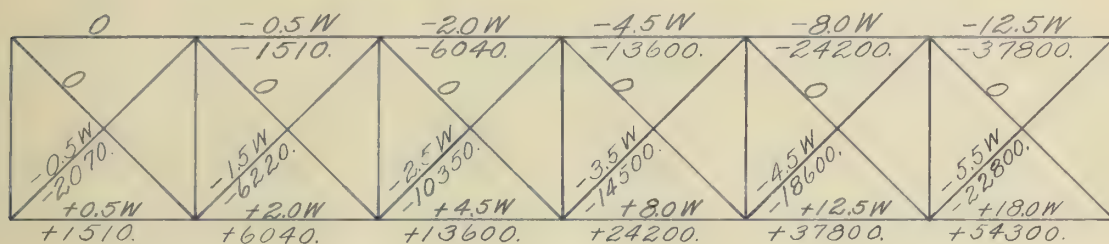
$$W \sec \theta = 4140$$

$$\tan \theta = 1.06$$

$$P = 150 \times 19 = 2850 \text{ lbs.}$$

$$\sec \theta = 1.454$$

Bottom Lateral System.
 Bridge Open.
 Dead Load Stresses



$$W = 150. \times 19. = 2850. \text{ lbs.}$$

$$\text{Sec. } \theta = 1.454.$$

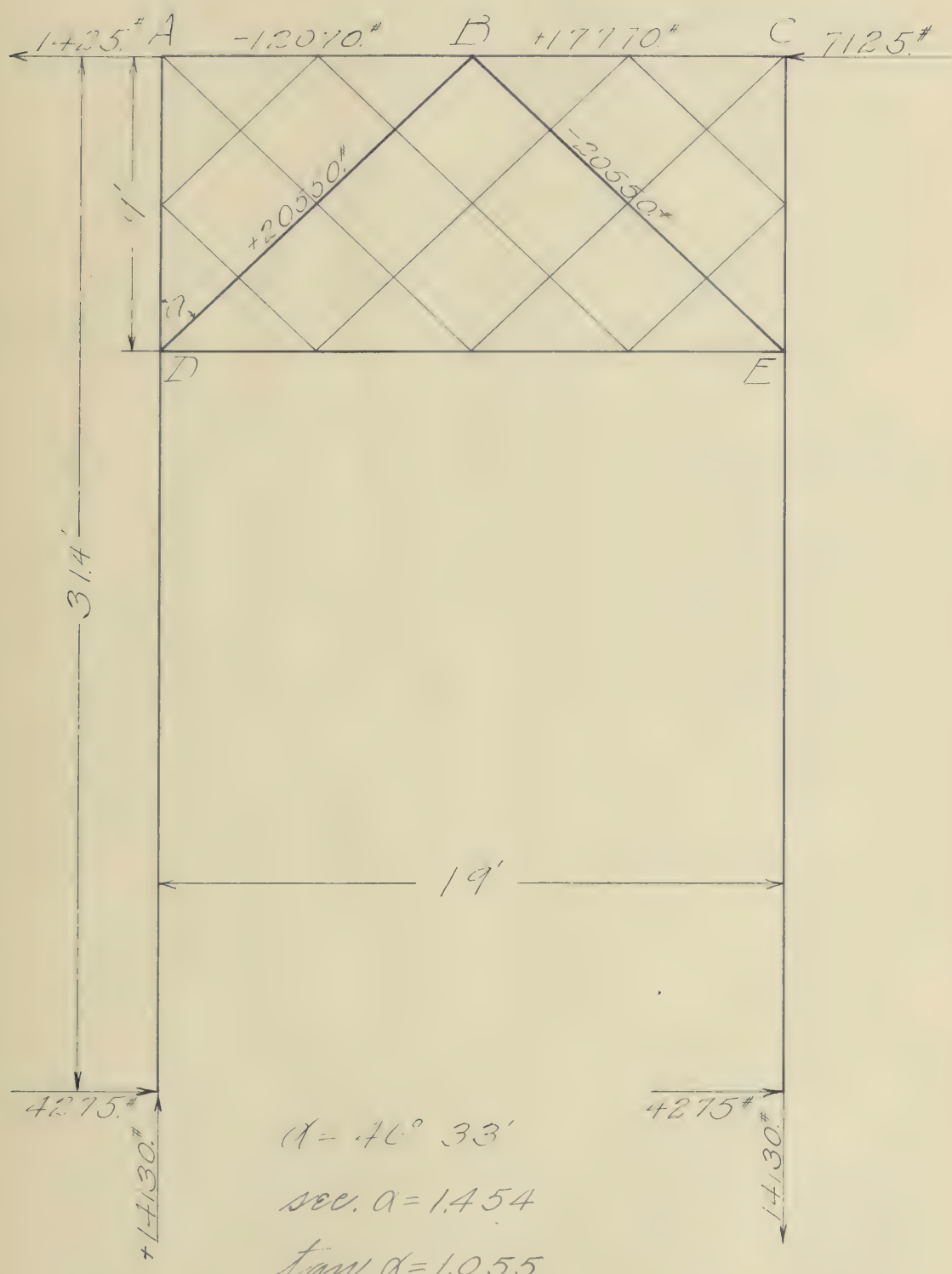
$$\theta = 46^{\circ} - 33'$$

$$W \tan \theta = 3020.$$

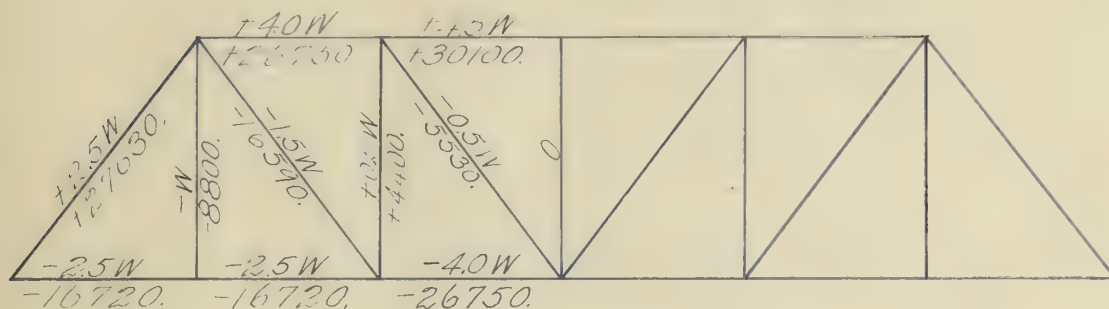
$$\tan \theta = 1.06$$

$$W \sec \theta = 4140.$$

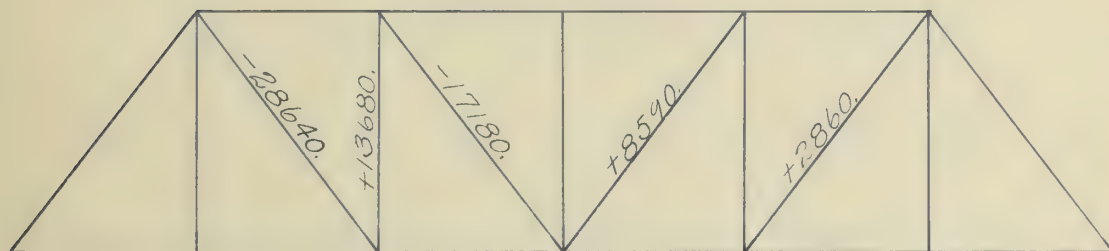
C
Portal



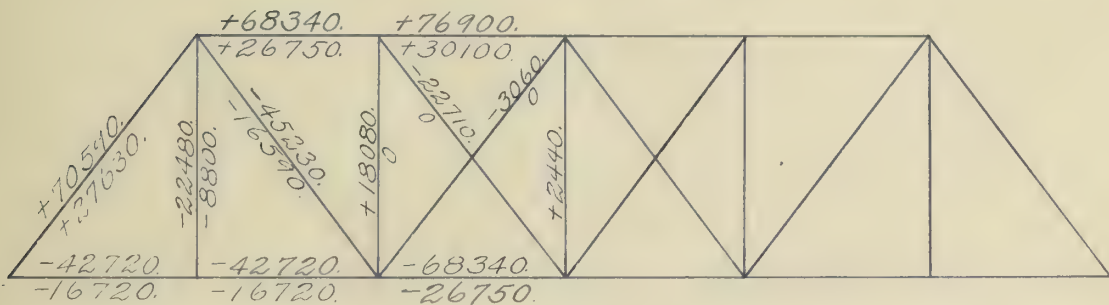
Stress in Truss
 Bridge Load
 Dead Load



Live Load



Max. and Min.



$$W = 8800 \text{ lbs.}$$

$$P = 13680 \text{ "}$$

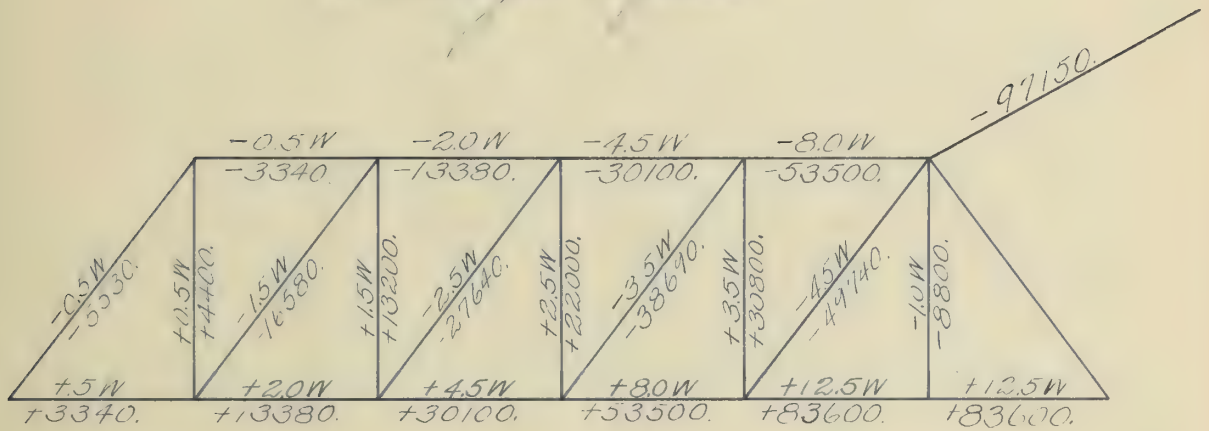
$$\tan \theta = 0.76$$

$$\sec \theta = 1.256$$

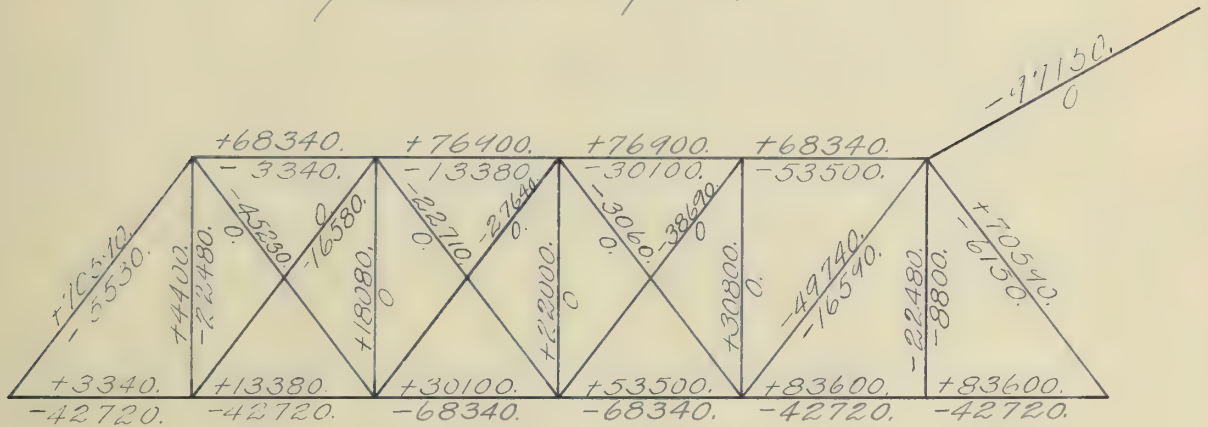
$$W \tan \theta = 6688$$

$$W \sec \theta = 11053$$

Stresses in Truss.
 at Bridge 15m.



*Stress in the
Max. and Min.*



Art. V.

Design of Truss Members.

U₄U₅ Bridge Closed

Length = 228 inches.

Stress, bridge closed = $+68340 + \frac{8}{10} = +111140$ lbs.

Wind stress bridge closed = $+4270$ lbs.

Allowed compressive stress bridge closed,

Live load, $P = 12000 - 55 \frac{L}{L}$

Dead load, $P = 24000 - 110 \frac{L}{L}$

Try two 12" - 20.5# channels with lacing.

Area of section = $2 \times 6.03 = 12.06$ sq. in., $r = 4.61$

Allowable live load stress = $12000 - 55 \frac{228}{4.61} = 9280$ lbs.

" dead " " = $24000 - 110 \frac{228}{4.61} = 18560$ "

Wt. of channels = $2 \times 20.5 \times 19 = 779$ lbs.

Add 20% for details then $W = 935$ lbs.

M due to weight = $\frac{1}{8} \times 935 \times 228 = 26650$.

I for section = $2 \times 128.1 = 256.2$, $y = 6$.

$f = \frac{26650 \times 6}{\frac{256.2 - 68340(228)^2}{32 \times 28000000}} = \frac{159900}{256.2 - 3.92} = 634$ lbs.

$634 < 10\%$ of allowed stress, so is neglected.

Live load $+ \frac{8}{10} = 67700$ lbs.

Dead " $+ \frac{8}{10} = 43440$ "

Area for live load = $\frac{67700}{9280} = 7.30$ sq. in.

" " dead load = $\frac{43440}{18560} = 2.34$ " "

Total required area = 9.64 sq. in.

$$\frac{68340}{9.64} = 7080 \text{ lbs.}$$

$$7080 + 25\% = 8850 \text{ lbs. allowed.}$$

$$\frac{68340 + 4270}{12.06} = 6020 \text{ lbs. per sq. in.}$$

6020 < 8850. therefore the section is safe for compression.

U₄U₅ Bridge Open.

$$\text{Stress} = -53500 + \frac{8}{10} = -96300 \text{ lbs.}$$

$$\text{Wind stress} = +22800 \text{ lbs. and } -12800 \text{ lbs.}$$

$$\text{Allowed stress} = \frac{3}{4} \times 25000 \text{ lbs.} = 18750 \text{ lbs.}$$

$$\text{Required area} = \frac{-96300}{18750} = 5.14 \text{ sq. in.}$$

$$\text{Area of section selected above} = 12.06 \text{ sq. in.}$$

$$\frac{96300 + 12800}{12.06} = 9050 \text{ lbs. per sq. in.}$$

9050 < 18750. therefore the section is safe for the maximum tensile stress.

U₃U₄ Bridge Closed

$$\text{Stress, bridge closed} = +76900 \text{ lbs.}$$

$$76900 + \frac{8}{10} \cdot 30100 = 100980 \text{ lbs.}$$

$$\text{Wind stress} = +5700 \text{ lbs.}$$

Try two 12"-20.5# channels with lacing two sides.

$$\text{Area of section} = 2 \times 6.03 = 12.06 \text{ sq. in.}$$

$$l = 228 \text{ in. } N = 4.61$$

$$\text{Allowed live load stress} = 12000 - 55 \frac{228}{4.61} = 9280 \text{ lbs}$$

$$\text{Allowed dead load stress} = 24000 - 110 \frac{228}{4.61} = 18560 \text{ lbs}$$

The stress due to weight is too small to be considered.

$$\text{Live load} + \frac{8}{10} = +61480 \text{ lbs.}$$

$$\text{Dead load} + \frac{8}{10} = 39500 \text{ lbs.}$$

$$\text{Area for live load} = \frac{61480}{9280} = 6.63 \text{ sq. in.}$$

$$\text{Area for dead load} = \frac{39500}{18560} = 2.13 \text{ sq. in.}$$

$$\text{Total required area} = 8.76 \text{ sq. in.}$$

$$\frac{76900}{8.76} = 8780 \text{ lbs.}$$

$$8780 + 25\% = 10975 \text{ lbs. allowed.}$$

$$\frac{76900 + 5700}{12.06} = 6850 \text{ lbs.}$$

$6850 < 10970$, therefore the section is safe for compression.

$U_3 U_4$ Bridge Open

When the bridge is open, both the dead load and wind stresses are smaller than those in $U_4 U_5$, therefore two 12"-20.5# channels will be safe in tension, and will be used for this member.

U_2U_3 and U_1U_2

Use same section as for L_3L_4 and L_4L_5

L_5L_6 and L_4L_5 Bridge Open.

Stress = +83600 lbs.

$83600. + \frac{3}{10}$ of -42720. = 117780. lbs.

Wind stress = +54300. lbs.

Use two 12. inch 20.5 lb channels with flanges.

Area of section = $2 \times 6.03 = 12.06$ sq. in.

$C = 22.8$ inches. $r = 4.61$

Allowable axial load stress = $\frac{3}{4}(24000 - 110. \frac{228}{4.61}) = 13920$ lbs.

Stress due to weight is too small to be considered.

Area required = $\frac{117780}{13920} = 8.47$ sq. in.

$\frac{83600}{8.47} = 9870$ per sq. in.

$9870. + 25\% = 12333$ lbs.

$\frac{83600. + 54300.}{12.06} = 11430$ lbs.

$11430. < 12338$. Therefore the section is safe for compression.

L_5L_6 and L_4L_5 Bridge Closed.

Stress = -42720. lbs.

$42720. + \frac{3}{10} = -76840$ lbs.

Wind stress = 0.

These stresses are less than those in U_4U_5 when the bridge is open. The allowable stress is greater therefore the 12 in. 20.5 lb. channel will be safe in tension in L_5L_6 .

L_3L_4 Bridge Open.

Stress = +53500. lbs.

Wind stress = +24200. lbs.

Use same section as for L_4L_5

L_3L_4 Bridge Closed.

Stress = -68340. lbs.

$68340 + \frac{8}{10}$ of 53500. = -111140. lbs.

Wind stress = -24200. lbs.

Try two 12 inch 20.5 lb. channels.

Area of section = $2 \times 6.03 = 12.06$ sq in.

Allowed live load stress = 12500. lbs.

Allowed dead load stress = 25000. lbs.

$f = \frac{26650. \times 6.}{256.2 + \frac{68340. (2.28)^2}{32 \times 28000000}} = \frac{159900.}{256.2 + 3.92} = 615. \text{ lbs.}$

615 lbs. = 10% of allowed so is neglected.

Live load + $\frac{8}{10}$ = -67640.

Dead load + $\frac{8}{10}$ = -43500.

$$\text{Area for live load} = \frac{67640.}{12500.} = 5.42 \text{ sq. in.}$$

$$\text{Area for dead load} = \frac{43500.}{25000} = 1.74 \text{ sq. in.}$$

$$\text{Total required area} = 7.16 \text{ sq. in.}$$

$$\frac{68340.}{7.16} = 9550. \text{ lbs.}$$

$$9550. + 25\% = 11940. \text{ lbs.}$$

$$\frac{68340. + 24200.}{12.06} = 7680. \text{ lbs.}$$

7680. < 11940. therefore the section is safe in tension.

L_0L_1 L_1L_2 L_2L_3

Use same section as for L_3L_4

L_0L_1 Bridge closed.

$$\text{Live load} = +70510. \text{ lbs.}$$

$$\text{Live load stress} = +42960. \text{ lbs.}$$

$$\text{Dead load stress} = +27130. \text{ lbs.}$$

$$\text{Tension stress, bridge open} = -5530. \text{ lbs.}$$

$$\text{Tension stress, bridge closed} = 1440. \text{ lbs.}$$

$$\text{Compression stress, bridge closed} = 114420. \text{ lbs.}$$

Use two 12 inch 20.5 lb. channels with lacing on sides, distance back to back of angles = 9.6 inches.

$$\text{Then } I_x \text{ in direction of bending} = 372.62$$

$$c = 7.74 \text{ inches.}$$

$$\frac{11 \times 1120 \times 7.77}{37262 - \frac{70540(377)^2}{28000000}} = \frac{8894170}{37262 - 3583} = 26440. \text{ lbs.}$$

$$\text{Live load} = \frac{4216}{7054} \times 8 \times (-5530) = +45650. \text{ lbs.}$$

$$\text{Dead load} = \frac{2763}{7054} \times 8 \times (-5530) = +29360. \text{ lbs.}$$

The stress due to the weight of the member is too small to be considered.

$$\text{Allowable live load stress} = 10000 - 45 \frac{377}{461} = 6320.$$

$$\text{Allowable dead load stress} = 20000 - 90 \frac{377}{461} = 12640.$$

$$\text{Area for live load} = \frac{45650}{6320} = 7.23 \text{ sq. in.}$$

$$\text{Area for dead load} = \frac{29360}{12640} = 2.32 \text{ sq. in.}$$

$$\text{Required area for dead and live load stresses} = 4.55 \text{ sq. in.}$$

$$\frac{70540}{4.55} = 15500. \text{ lbs. allowed unit stress.}$$

$$\frac{70540 + 26440}{7400 + 12640} = 11.1 \text{ sq. in. total required.}$$

Use two 12 inch 20.5 lb. channels - 12.06 sq. in. Therefore the 12 inch 20.5 lb. channels will be used.

L.O. Bridge per.

Stress = 15500 lbs.

The two 12 inch 20.5 lb. channels will be required.

U.L-6

Use the same section as for L.U.

U.L, Bridge Open

Stress when bridge is open = + 4400. lbs.

Stress when bridge is closed = 22480. lbs

$4400 + \frac{8}{10} \cdot 4400 = 7920$ lbs.

Try two 8 inch - 11.25 lb. channels with lining.

$l = 300$ inches. $n = 3.10$

Area of section = 6.7 sq. in.

Allowable stress = $\frac{3}{4} 20500 - 40 \frac{300}{3.10} = 8450$ lbs.

Area required = $\frac{7920}{8450} = .94$ sq. in.

Therefore section is safe.

U.L, Bridge closed.

Stress = -22480. lbs.

Live load = $\frac{1368}{2248} \times \frac{8}{10} \times 4400 = -15820$ lbs.

Dead load = $\frac{880}{2248} \times \frac{8}{10} \times 4400 = -10180$ lbs.

Allowed live load stress = 12500. lbs.

Allowed dead load stress = 25000. lbs.

Area for live load = $\frac{15820}{12500} = 1.27$ sq. in.

Area for dead load = $\frac{10180}{25000} = .41$ sq. in.

Total area required = 1.68 sq. in.

Therefore the 8-inch channels will be

sufficient. A smaller section could not be used for then L would be greater than 100 ft.

U_4L_4 Bridge Closed.

Stress = +30800 lbs.

Let two 8 inch 11.25 lb. channels in. facing.
 $L = 300$ inches. $r = 3.10$

Area of section = 6.7 sq. in.

Allowed unit stress = $\frac{3}{4} 20000 - 10 \frac{300}{3.10} = 8450$ lbs.

$$\frac{30800}{8450} = 3.65 \text{ sq. in.}$$

Therefore the two 8-inch 11.25 channels will be used.

U_2L_2 and U_3L_3

See same section as for U_4L_4

U_5L_5 Bridge Closed.

Stress = -13680 lbs. for live load.

Stress = -8800 lbs. for dead load.

Allowable live load stress = 12500 lbs.

Allowable dead load stress = 25000 lbs.

$$\text{Area for live load} = \frac{13680}{12500} = 1.09 \text{ sq. in.}$$

$$\text{Area for dead load} = \frac{8800}{25000} = .35 \text{ sq. in.}$$

Total area required - 1.44 sq. in.
 Section 8 into 11.25 lb channels with
 lacing two side conform to code
 as the unit is not limiting plate.

U₁L₂ Bridge Closed.

Tension = -45230. lbs.

Live load stress = -28640. lbs.

Dead load stress = -10576. lbs.

Allowable live load stress = 12500. lbs.

Allowable dead load stress = 25000. lbs.

Area required = $\frac{28640}{12500} = 2.31$ sq. in.

Area required = $\frac{10576}{25000} = .42$ sq. in.

Total area required = 2.73 sq. in.

Use two 2" x 3" lvs. width of section = 228 in.

$W = 2 \times 5.10 \times 3.14 = 320$ lbs. $L = 3 \times 5 = 15'$

$M = \frac{1}{8} \times 320 \times 228 = 9120$

$f = \frac{9120 \times 1}{1.0 + \frac{45230(228)^2}{10 \times 28000000}} = \frac{9120}{1.0 + 8.4} = 970$ lbs.

970 lbs. is less than 10% of 25000, so it is
 needed.

Therefore two 2" x 3" lvs. are required.

U₂L₁ Bridge floor.

$$\text{Stress} = -16580 \text{ lbs.}$$

$$\text{Allowable stress} = \frac{3}{4} \times 25000 \text{ lbs.} = 18750 \text{ lbs.}$$

$$\text{Area required} = \frac{16580}{18750} = 0.89 \text{ sq. in.}$$

Try two $\frac{3}{4}$ in square bars with turn buckles.

$$\text{Area of two bars} = 2 \times 0.56 = 1.12 \text{ sq. in.}$$

$$\text{Weight of two bars} = 1.91 \times 31.4 = 59.9 \text{ lbs.}$$

$$M = \frac{1}{8} \times 59.9 \times 228 = 1710. \quad I = 2 \times 317 = 0.63$$

$$f = \frac{1710 \times 0.38}{0.63 + \frac{16580(228)^2}{280000000}} = \frac{650}{0.63 + 3.08} = 175 \text{ lbs}$$

Since 175 is less than 10% of 18750 it is neglected.

The two $\frac{3}{4}$ inch square bars will carry the stress but to conform to Cooper art. 47, the bars must be of larger size.

Use two circular bars 1 in. in diameter.

U₂L₃ Bridge floor.

$$\text{Stress} = -22710 \text{ lbs.}$$

$$\text{Live load stress} = -17180 \text{ lbs.}$$

$$\text{Dead load stress} = -5530 \text{ lbs.}$$

$$\text{Area for live load} = \frac{17180}{12500} = 1.37 \text{ sq. in.}$$

$$\text{Area for dead load} = \frac{5530}{25000} = 0.22 \text{ sq. in.}$$

$$\text{Total area required} = 1.59 \text{ sq. in.}$$

Try two $1\frac{3}{4} \times \frac{1}{2}$ bars. Area of section = 1.15 sq. in.
 The stress due to the weight of the member is small so is neglected.

The two $1\frac{3}{4} \times \frac{1}{2}$ bars will be used.

U₃L₂ Bridge Open.

Stress = -27640 lbs.

Allowable stress = $\frac{3}{4}(25000) = 18750$ lbs.

Area required = $\frac{27640}{18750} = 1.48$ sq. in.

Use two circular bars 1 in. in diameter with turnbuckles. Area of section = 1.57 sq. in.

The stress due to the weight of the member is small so is neglected.

Therefore these two 1 inch circular bars will be used.

U₃L₄ Bridge Closed.

Stress = -3060 lbs.

Live load stress = -3060

Area for live load = $\frac{3060}{12500} = 0.25$ sq. in.

Try one 1 inch circular bar with turn buckle.

Area of section = 0.79 sq. in.

This 1 inch circular bar will be used.

U_4L_3 Bridge Open.

Stress = -38690 lbs.

Allowable stress = $\frac{3}{4}(25000) = 18750$ lbs.

Area required = $\frac{38690}{18750} = 2.06$ sq. in.

Try two $2\frac{1}{4} \times \frac{1}{2}$ bars

Area of section = $2 \times 1.13 = 2.25$ sq. in.

The stress due to the weight is small so is neglected.

Use the two $2\frac{1}{4} \times \frac{1}{2}$ bars.

U_5L_4 Bridge Open

Stress = -49740 lbs.

Allowable stress = $\frac{3}{4} \times 25000 = 18750$ lbs.

Area required = $\frac{49740}{18750} = 2.66$ sq. in.

When the bridge is closed, the area required is 2.95 sq. in.; as determined for U_1L_2 , which is the corresponding member at the other end of the span. Therefore the same size bars will be used for U_5L_4 as for U_1L_2 , namely two $2 \times \frac{3}{4}$ bars.

Lifting Bars. Bridge Open.

Stress = -97150 lbs.

Allowable stress = $\frac{3}{4} \times 25000 = 18750$ lbs.

$$\text{Area required} = \frac{97150}{18750} = 5.19 \text{ sq. in.}$$

Two $2\frac{3}{4} \times 1$ bars

$$\text{Area} = 2 \times 2.75 = 5.5 \text{ sq. in.}$$

$$\text{Weight of two bars} = 2 \times 9.35 \times 32.2 = 602.14 \text{ lbs}$$

$$M = \frac{1}{8} \times 602.14 \times 342 = 25740. \quad I = 3466$$

$$f = \frac{25740 \times 1.375}{3466 + \frac{97150(342)^2}{2800000000}} = \frac{35350}{3466 + 40.6} = 800. \text{ lbs}$$

Since 800 is less than 10% of 18750, it is neglected.

The two $2\frac{3}{4} \times 1$ bars will be used

Art. VI

Design of Portal Top Strut A.C.

(a) Compressive stress = +17770. lbs.

Try two $4 \times 4 \times \frac{5}{16}$ angles with $\frac{3}{8}$ " space between.

$$\text{Area of section} = 4.8 \text{ sq. in.} \quad n = 1.8, \quad l = 216. \text{ in.}$$

$$\text{Allowable stress} = 13000 - 60 \frac{216}{1.8} = 5800. \text{ lbs.}$$

$$\frac{17770}{5800} = 3.06 \text{ sq. in. required.}$$

Therefore the section is safe in compression.

(b) Tensile stress = -12070. lbs.

$$\text{Net area of section} = 4.8 - .52 = 4.18 \text{ sq. in.}$$

Allowable stress = 18000. lbs.

$$\frac{12070}{18000} = 0.67 \text{ sq. in. required.}$$

Therefore the section is safe in tension.

The two $4 \times 4 \times \frac{5}{16}$ angles will be used.

Stout (B.D.).

Length = 153. inches.

Compressive stress = 20550. lbs.

Try two $4 \times 4 \times \frac{5}{16}$ angles with $\frac{3}{8}$ between.

Area of section = 4.8 sq. in. $u = 1.3$

Allowed stress = 13000. $\rightarrow 60 \frac{153}{1.8} = 7900$ lbs.

$$\frac{20550}{7900} = 2.6 \text{ sq. in. required.}$$

Use two $4 \times 4 \times \frac{5}{16}$ angles will be used.

Member E-E.

Stress = 20550 lbs.

Allowable stress = 18000. lbs.

Use the two $4 \times 4 \times \frac{5}{16}$ angles.

The other members of the portal are added for greater stability. The brace members use $2 \times 2 \times \frac{3}{8}$ angles. Use $\frac{3}{8}$ plates for the connections.

Art. VII.

Top Lateral Stents.

Stent at U_4 Bridge Open

Stress = +9970. lbs.

Use four $4 \times 3 \times \frac{5}{16}$ inches with $\frac{1}{4}$

spacing as shown in sketch

 $I = 226$, $r = 1.88$, $area = 8.36$

$$Allowable stress = \frac{3}{4} \left(13000. - 60 \frac{226}{1.88} \right) = 4340. \text{ lbs.}$$

$$Area required = \frac{9970}{4340} = 2.3 \text{ sq. in.}$$

The stress due to the weight is small so is neglected, as the area of the section chosen is greater than required. But the size of the section is determined by the condition that $r = r' > \frac{L}{120}$

This same condition will determine the section for the other stents.

Therefore use the section as given above for the stents at U_2 , U_3 and U_4 .

Art. VIII.

Top Lateral Diagonals.

 $U_4 U_5$ Bridge Open.

Stress = -14100. lbs.

$$Allowable stress = \frac{3}{4} \times 18000. = 13500. \text{ lbs.}$$

Try a $4 \times 3 \times \frac{5}{16}$ angle, area - 2.09 sq. in.
 Weight - $7.1 \times 26.17 = 186$ lbs.
 $M = \frac{1}{8} \times 186 \times 26.17 \times 12 = 7300$.

$$f = \frac{7300 \times 0.76}{1.65 + \frac{14100(314)^2}{32 \times 28000000}} = \frac{5548}{1.65 + 1.55} = 1730 \text{ lbs.}$$

$$\frac{14100 + 1730}{13500 + 10\%} = 1.07 \text{ sq. in. required}$$

Effective section of angles - $\frac{4}{7} \times 2.09 = 1.19 \text{ sq. in.}$
 The $4 \times 3 \times \frac{5}{16}$ angles will be used.

Use the same size angles for
 the top lateral diagonals.

Art. IX

Bottom Lateral Diagonals.

$L_5 L_6$ Bridge Open.

$$\text{Stress} = -22800 \text{ lbs.}$$

$$\text{Allowable stress} - \frac{3}{4} \times 18000 = 13500 \text{ lbs.}$$

Try a $5 \times 3 \frac{1}{2} \times \frac{3}{8}$ angle, area - 3.05 sq. in.
 Weight - $10.4 \times 26.17 = 272$ lbs.

$$M = \frac{1}{8} \times 272 \times 26.17 \times 12 = 10680$$

$$f = \frac{10680 \times 0.86}{3.18 + \frac{22800(314)^2}{32 \times 28000000}} = \frac{9185}{3.18 + 2.51} = 1610 \text{ lbs.}$$

$$\frac{22800 + 1610}{13500 + 10\%} = 1.64 \text{ sq. in. required.}$$

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Efficient use of angle $\frac{5}{8} \times 3.05 = 171 \text{ sq. in.}$
 Therefore the $5 \times 3\frac{1}{2} \times \frac{3}{8}$ angles will be used.

$L_4 L_5$ Bridge Open
 Stress = 18000. lbs.
 Use the $5 \times 3\frac{1}{2} \times \frac{3}{8}$ angles

$L_0 L_1$ Bridge Closed.
 Stress = -20700. lbs.
 Use the $5 \times 3\frac{1}{2} \times \frac{3}{8}$ angle.

$L_3 L_4$ Bridge Open.
 Stress = -14500. lbs.
 Allowable stress = $\frac{3}{4} \times 18000 = 13500$ lbs.
 Try a $4 \times 3 \times \frac{5}{16}$ angle. Area = 2.09 sq. in.
 Weight = $7.1 \times 26.17 = 186$ lbs.
 $M = \frac{1}{8} \times 186 \times 26.17 \times 12 = 7300$.

$$f = \frac{7300 \times 0.76}{1.65 + \frac{14500(314)^2}{32 \times 28000000}} = \frac{5548}{1.65 + 1.60} = 1700 \text{ lbs.}$$

$$\frac{14500 + 1700}{13500 + 1070} = 1.09 \text{ sq. in. required.}$$

Effective section. $\frac{4}{7} \times 2.09 = 1.19 \text{ sq. in.}$

Therefore the $4 \times 3 \times \frac{5}{16}$ angle will be used.

$L_2 L_3$ Bridge Open

Stress = -10350 lbs.

Use the $4 \times 3 \times \frac{5}{16}$ angle.

$L_1 L_2$ Bridge Closed.

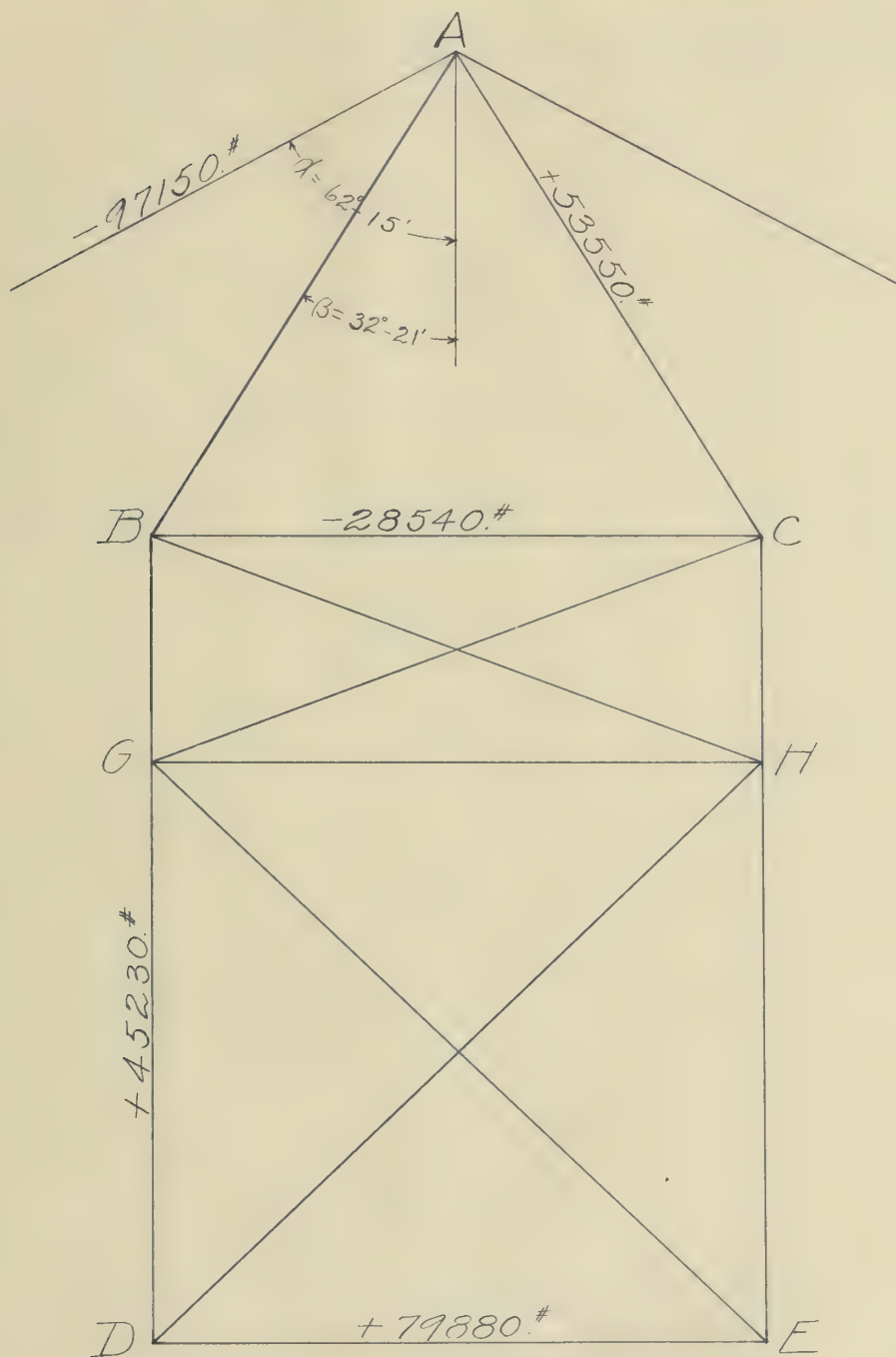
Stress = -13120 lbs.

Use the $4 \times 3 \times \frac{5}{16}$ angle.

PART 2

Design of Tower =

Art. I
Dead Load Stresses.

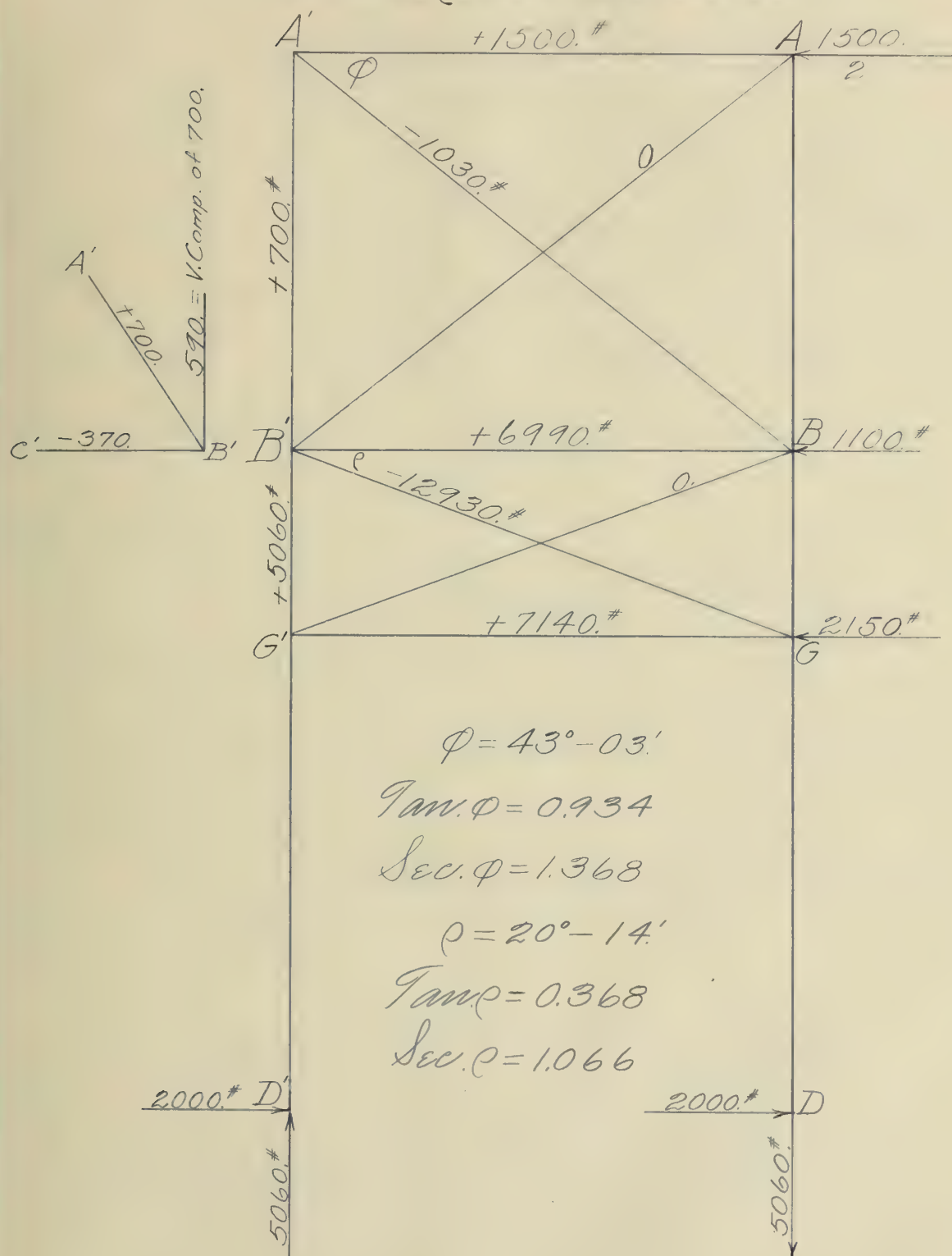


$$\sec \alpha = 2.148$$

$$\sec \beta = 1.184$$

$$\tan \beta = 0.633$$

Art. II.
Wind Load Stresses.



Art. III.

Design of Members.

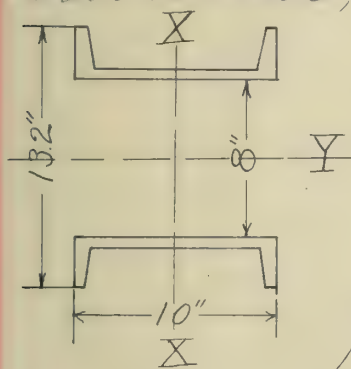
Post B'D' Bridge Open.

Dead load stress = + 45230.

Direct wind stress = + 5060.

Bending due to wind = $S = \frac{Mc}{I}$, $M = 432000$.

Try two 10-inch 15 lb. channels with lacing
two sides, distance back to back of $\angle$ = 8 inches



Area of section = 8.92 sq. in.

$$I_x = 133.8, \quad r_x = 3.87$$

$$I_y = 196.64$$

$$f = \frac{432000 \times 6.6}{196.64 - \frac{45230(216)^2}{32 \times 28000000}} = \frac{2851200}{196.64 - 2.35} = 14670 \text{ lbs.}$$

Allowed dead load stress = $\frac{3}{4}(20000 - 90 \frac{300}{3.87}) = 9750$.

Wind stress is too small to be considered.

$$\frac{45230 + 14670}{9750 + 10\%} = 5.58 \text{ sq. in. required.}$$

The two 10-inch 15 lb. channels will be
used in the posts of the tower.

Strut A'B' Bridge Open.

Dead load stress = + 53550. lbs.

Wind load stress = + 700. lbs.

Try two 8-inch $11\frac{1}{4}$ lb. channels with lacing.

Area of section = 6.70 sq. in.

$l = 213$ inches $r = 3.10$

Allowed dead load stress $= \frac{3}{4}(20000 \text{ to } \frac{213}{3.10}) = 10370$ lbs.

The stress due to the weight is too small to be considered.

The wind load is less than 25% of the dead load stress and is therefore neglected.

Area required $= \frac{53550}{10370} = 5.16$ sq in.

The two 8 inch $11\frac{1}{4}$ lb. channels will be used for the four top inclined struts.

Member BC, Bridge Open.

Stress $= -28540$ lbs.

Allowed stress $= \frac{3}{4}(25000) = 18750$ lbs

Try a $5 \times 3 \times \frac{3}{8}$ " angle fastened with the long leg vertical. Area of section $= 2.86$

$I = 7.37$, $W = 19 \times 9.7 = 184$ lbs.

$M = \frac{1}{8} \times 184 \times 19 \times 12 = 5244$.

$f = \frac{5244 \times 3.3}{7.37 + \frac{28540(2.28)^2}{32 \times 28000000}} = \frac{17305}{7.37 + 1.66} = 1916$ lbs.

$\frac{28540 + 1916}{18750 + 10\%} = 1.47$ sq in required.

Effective section of angle $= \frac{5}{8} \times 2.86 = 1.79$ sq in.

The $5 \times 3 \times \frac{3}{8}$ " angle will be used for BC.

1314, 22, 517, 52, 45
Use 4" x 3" x $\frac{5}{16}$ " angles

Strut D.E, Bridge Open
Stress = +79880 lbs.

Use same section as for $L_5 L_6$, namely
two 12-inch 20.5 lb channels.

Strut A.A' Bridge Open
Wind stress, Bridge Open = +1500 lbs.
This stress would require a small section
only, but the size of the section is de-
termined by the condition that $v = \frac{L}{120}$
 $L = 228$ $\therefore v$ must = $\frac{228}{120} = 1.90$

Use four 4" x 3" x $\frac{5}{16}$ " angles with
 $\frac{3}{8}$ " lacing as shown in sketch.
Least $v = 1.93$, Area of section = 8.36
Therefore this section will be used.

Strut B.B'
Use the same section as for A.A' for the
same reason

Sheet 49

Use the same section as for 18 for the same reason

Diagonal B'G, Bridge G'F
Wind stress = -12930 lbs.

Allowable stress = $\frac{3}{4}(18000) = 13500$ lbs.

Try a $4" \times 3" \times \frac{5}{16}"$ angle. Area of sec. = 2.09 sq. in.

Effective section = $\frac{4}{7} \times 2.09 = 1.19$ sq. in.

The $4" \times 3" \times \frac{5}{16}"$ angle will be used.

Conclusion.

A complete design of a swing bridge would include the details and also the turning and lifting machinery; but owing to the shortness of the time available for this thesis, the above mentioned parts of the design will not be considered.





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